US009143281B2

(12) **United States Patent**
Malladi

(10) **Patent No.: US 9,143,281 B2**
(45) **Date of Patent: Sep. 22, 2015**

(54) **BLIND DECODING OF UPLINK CONTROL CHANNELS**

(75) Inventor: **Durga Prasad Malladi**, San Diego, CA (US)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1597 days.

(21) Appl. No.: **12/576,867**

(22) Filed: **Oct. 9, 2009**

(65) **Prior Publication Data**

US 2011/0085502 A1 Apr. 14, 2011

(51) **Int. Cl.**

H04W 4/00	(2009.01)
H04L 1/16	(2006.01)
H04L 1/00	(2006.01)
H04W 72/04	(2009.01)
H04W 72/12	(2009.01)

(52) **U.S. Cl.**

CPC ***H04L 1/1664*** (2013.01); ***H04L 1/003*** (2013.01); ***H04L 1/0026*** (2013.01); ***H04L 1/0027*** (2013.01); ***H04L 1/1671*** (2013.01); *H04W 72/0406* (2013.01); *H04W 72/1263* (2013.01)

(58) **Field of Classification Search**

CPC H04L 1/1671; H04W 72/0406; H04W 72/1263

USPC 370/329

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,281,201	B2 *	10/2012	Kim et al.	714/748
2008/0311919	A1	12/2008	Whinnett et al.	
2009/0042511	A1	2/2009	Malladi	
2009/0046582	A1	2/2009	Sarkar et al.	
2009/0073914	A1	3/2009	Sun et al.	
2009/0073922	A1	3/2009	Malladi et al.	
2009/0110038	A1	4/2009	Montojo et al.	
2009/0201860	A1	8/2009	Sherman et al.	
2010/0135181	A1 *	6/2010	Earnshaw et al.	370/252
2010/0190505	A1 *	7/2010	Shiizaki et al.	455/452.1

(Continued)

FOREIGN PATENT DOCUMENTS

WO	2009045139	A1	4/2009

OTHER PUBLICATIONS

Motorola, Uplink Control Signaling with Persistent Scheduling, Nov. 5-9, 2007, 3GPP TSG-RAN # 51 R1-074699.*

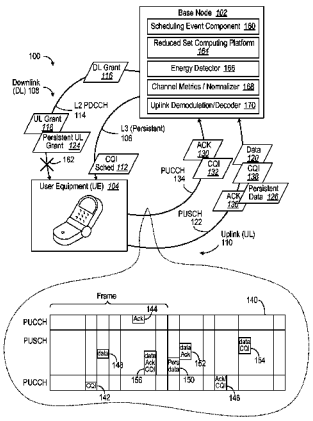
(Continued)

Primary Examiner — Shripal Khajuria
Assistant Examiner — Faisal Choudhury
(74) *Attorney, Agent, or Firm* — Jimmy Cheng

(57) **ABSTRACT**

In 3GPP LTE, the uplink ACK and CQI bits are jointly coded prior to transmission to maintain a low peak to average ratio (PAR) waveform. Further, when data needs to be transmitted, the uplink control channels are multiplexed with data prior to transmission. However, due to errors on downlink (DL) and uplink (UL) assignments, an evolved Base Node (eNB) receiver needs to employ a set of rules to decode the control channels, to minimize the number of blind decoding hypotheses. This innovation describes the rules employed by a receiver to reduce complexity and computational overhead in part by assuming that the UE is responding to grant on the downlink while providing for combinations in which one or more types of grants are not received. Energy detection in accordance with metrics and normalizing for differing power controls enables selecting the correct combination for decoding.

42 Claims, 9 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0195575	A1*	8/2010	Papasakellariou et al.	370/328
2011/0026478	A1*	2/2011	Lee et al.	370/329
2011/0032887	A1*	2/2011	Kishiyama et al.	370/329
2011/0143766	A1*	6/2011	Sun et al.	455/452.2
2011/0170514	A1*	7/2011	Eriksson et al.	370/329
2012/0058730	A1*	3/2012	Jitsukawa et al.	455/63.1
2013/0003681	A1*	1/2013	Earnshaw et al.	370/329
2013/0044714	A1*	2/2013	Kotecha et al.	370/329

OTHER PUBLICATIONS

Alcatel, Power Offsets to Support Data and Control Multiplexing for Persistent PUSCH, Jan. 11-15, 2008, 3GPP TSG-RAN WG1 # 52 R1-080912.*

Motorola, Uplink Control Signaling with Persistent Scheduling, Nov. 5-9, 2007, 3GPP TSA-RAN # 51 R1-074699.*

Texas Instruments, Comparison of Different ACK/NAK in CQI RS Transmission Schemes, Jan. 14-18, 2008, 3GPP TSG-RAN WG1 # 51 bis R1-080189.*

International Search Report and Written Opinion—PCT/US2010/052063, International Search Authority—European Patent Office—Apr. 1, 2011.

LG Electronics: "UL shared channel UE behaviour after ACK/NACK detection and UL synchronous", 3GPP Draft; R1-080277, UL Harq UE Behavior, 3rd Generation Partnership Project (3GPP) , Mobile Competence Centre; 650, Route Des Lucioles; F-06921 Sophia-Anti Polis Cedex; France, vol. RAN WG1, No. Sevilla, Spain; Jan. 8, 2008, XP050108799, [retrieved on Jan. 8, 2008] p. 3.

Qualcomm Europe: "Details of control and data multiplexing in PUSCH", 3GPP Draft, R1-080650, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre, 650, Route Des Lucioles, F-06921 Sophia-Antipolis Cedex, France, vol. RAN WGI, No. Sorrento, Italy, Feb. 6, 2008, XP050109151.

Taiwan Search Report—TW099134619—TIPO—Sep. 21, 2013.

* cited by examiner

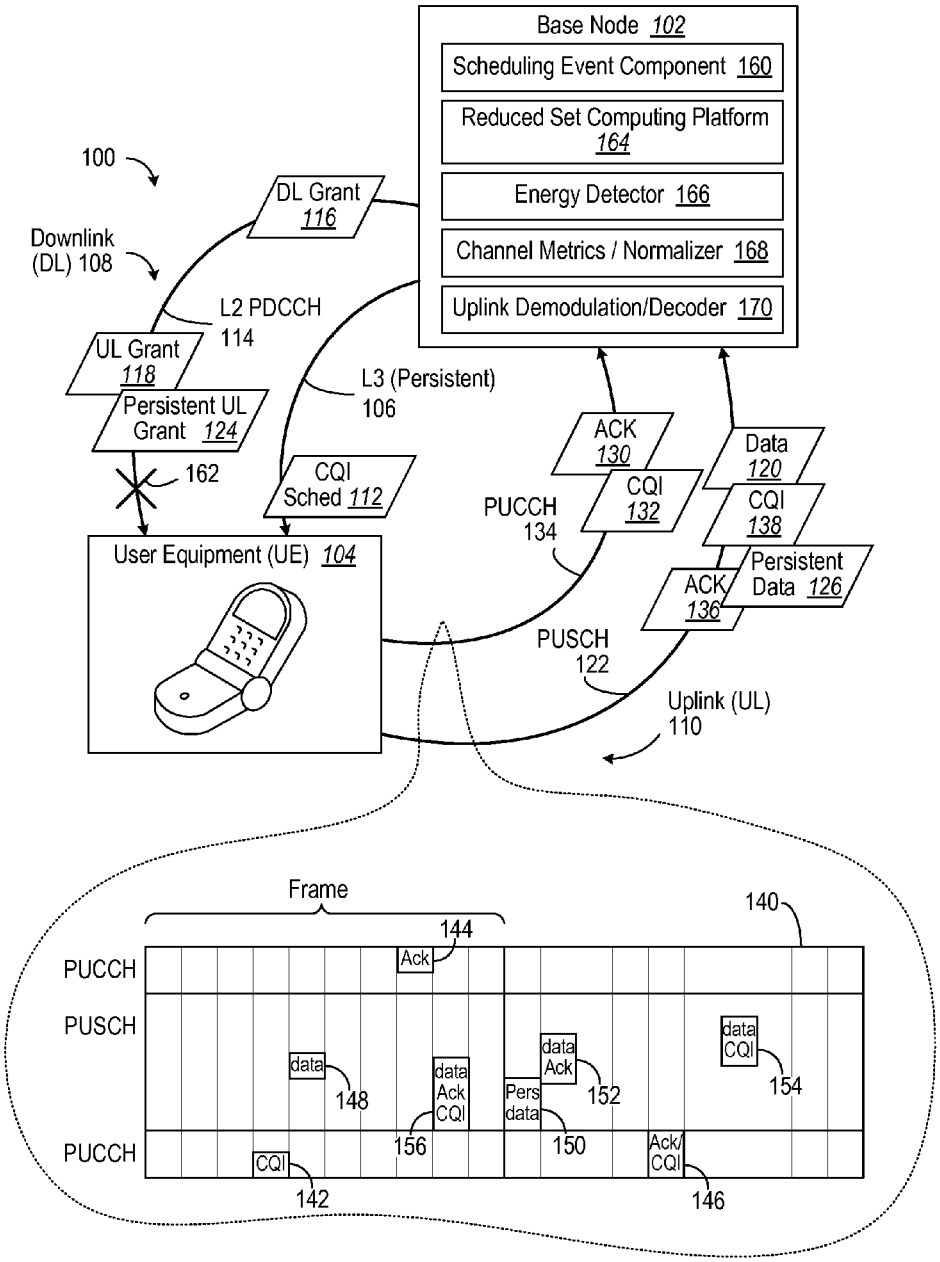

Base Node 102
Scheduling Event Component 160
Reduced Set Computing Platform 164
Energy Detector 166
Channel Metrics / Normalizer 168
Uplink Demodulation/Decoder 170
100
Downlink (DL) 108
DL Grant 116
L2 PDCCH 114
UL Grant 118
Persistent UL Grant 124
162
L3 (Persistent) 106
CQI Sched 112
User Equipment (UE) 104
ACK 130
CQI 132
PUCCH 134
Data 120
CQI 138
Persistent Data 126
ACK 136
PUSCH 122
Uplink (UL) 110
Frame
140
144
Ack
PUCCH
PUSCH
data
148
data Ack CQI
156
data Ack
152
Pers data
150
data CQI
154
PUCCH
CQI
142
Ack/ CQI
146

FIG. 1

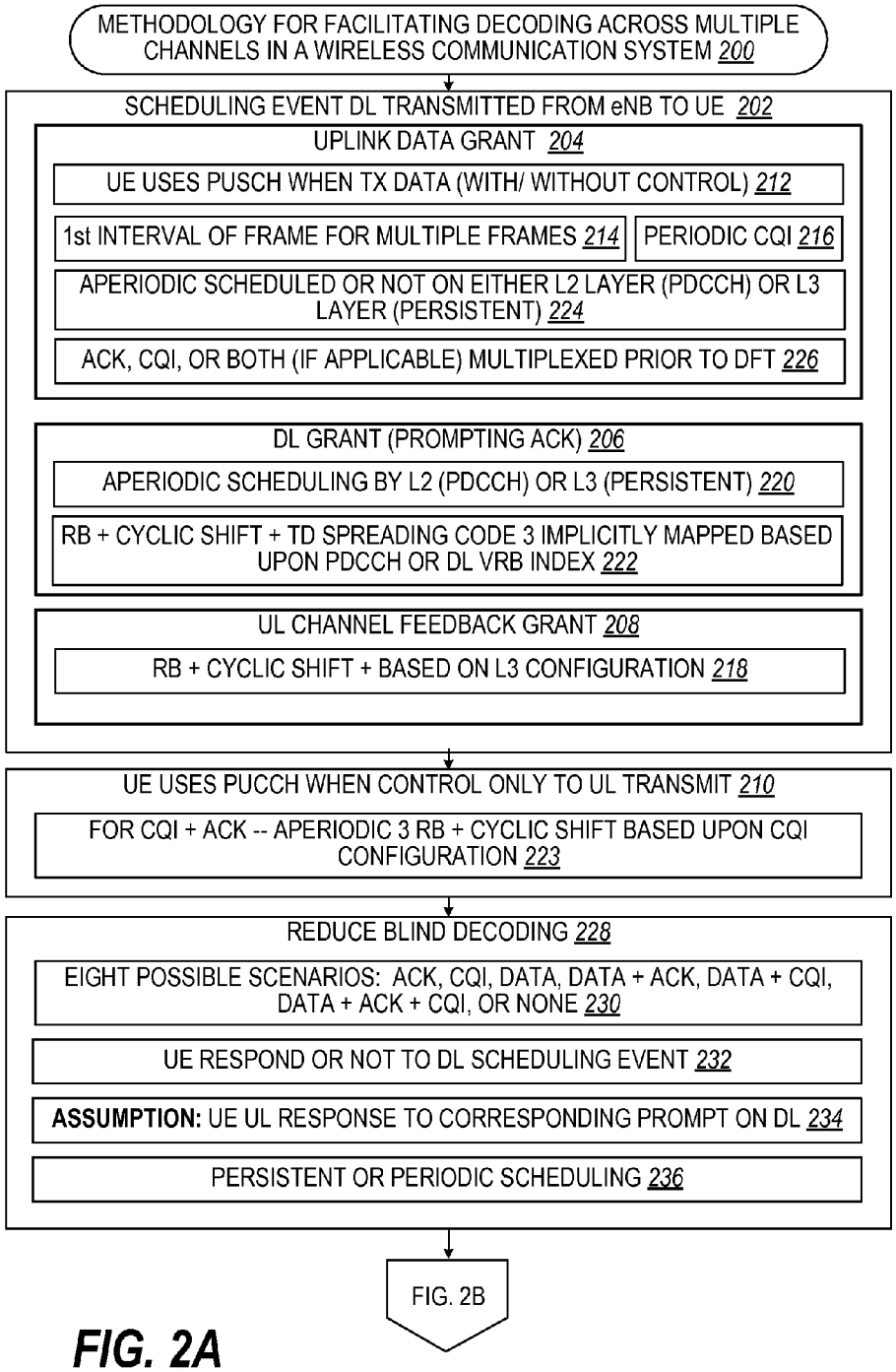

METHODOLOGY FOR FACILITATING DECODING ACROSS MULTIPLE CHANNELS IN A WIRELESS COMMUNICATION SYSTEM 200
SCHEDULING EVENT DL TRANSMITTED FROM eNB TO UE 202
UPLINK DATA GRANT 204
UE USES PUSCH WHEN TX DATA (WITH/ WITHOUT CONTROL) 212
1st INTERVAL OF FRAME FOR MULTIPLE FRAMES 214
PERIODIC CQI 216
APERIODIC SCHEDULED OR NOT ON EITHER L2 LAYER (PDCCH) OR L3 LAYER (PERSISTENT) 224
ACK, CQI, OR BOTH (IF APPLICABLE) MULTIPLEXED PRIOR TO DFT 226
DL GRANT (PROMPTING ACK) 206
APERIODIC SCHEDULING BY L2 (PDCCH) OR L3 (PERSISTENT) 220
RB + CYCLIC SHIFT + TD SPREADING CODE 3 IMPLICITLY MAPPED BASED UPON PDCCH OR DL VRB INDEX 222
UL CHANNEL FEEDBACK GRANT 208
RB + CYCLIC SHIFT + BASED ON L3 CONFIGURATION 218
UE USES PUCCH WHEN CONTROL ONLY TO UL TRANSMIT 210
FOR CQI + ACK -- APERIODIC 3 RB + CYCLIC SHIFT BASED UPON CQI CONFIGURATION 223
REDUCE BLIND DECODING 228
EIGHT POSSIBLE SCENARIOS: ACK, CQI, DATA, DATA + ACK, DATA + CQI, DATA + ACK + CQI, OR NONE 230
UE RESPOND OR NOT TO DL SCHEDULING EVENT 232
ASSUMPTION: UE UL RESPONSE TO CORRESPONDING PROMPT ON DL 234
PERSISTENT OR PERIODIC SCHEDULING 236
FIG. 2B

FIG. 2A

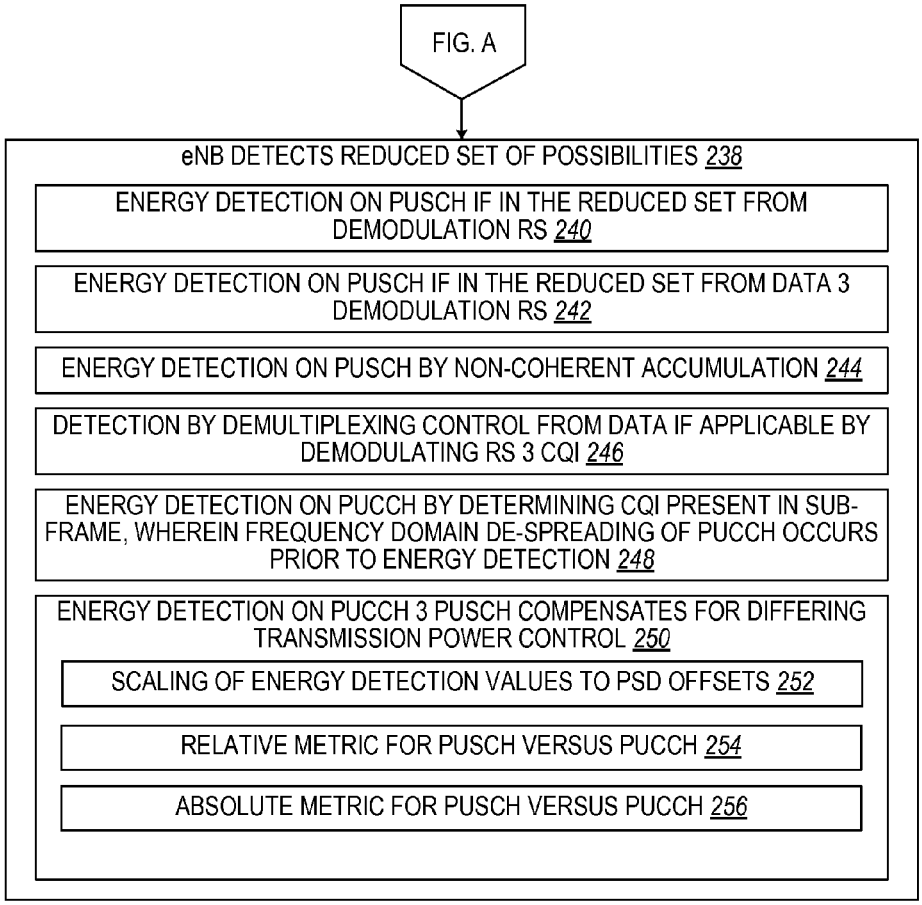


FIG. A
eNB DETECTS REDUCED SET OF POSSIBILITIES 238
ENERGY DETECTION ON PUSCH IF IN THE REDUCED SET FROM DEMODULATION RS 240
ENERGY DETECTION ON PUSCH IF IN THE REDUCED SET FROM DATA 3 DEMODULATION RS 242
ENERGY DETECTION ON PUSCH BY NON-COHERENT ACCUMULATION 244
DETECTION BY DEMULTIPLEXING CONTROL FROM DATA IF APPLICABLE BY DEMODULATING RS 3 CQI 246
ENERGY DETECTION ON PUCCH BY DETERMINING CQI PRESENT IN SUB-FRAME, WHEREIN FREQUENCY DOMAIN DE-SPREADING OF PUCCH OCCURS PRIOR TO ENERGY DETECTION 248
ENERGY DETECTION ON PUCCH 3 PUSCH COMPENSATES FOR DIFFERING TRANSMISSION POWER CONTROL 250
SCALING OF ENERGY DETECTION VALUES TO PSD OFFSETS 252
RELATIVE METRIC FOR PUSCH VERSUS PUCCH 254
ABSOLUTE METRIC FOR PUSCH VERSUS PUCCH 256

FIG. 2B

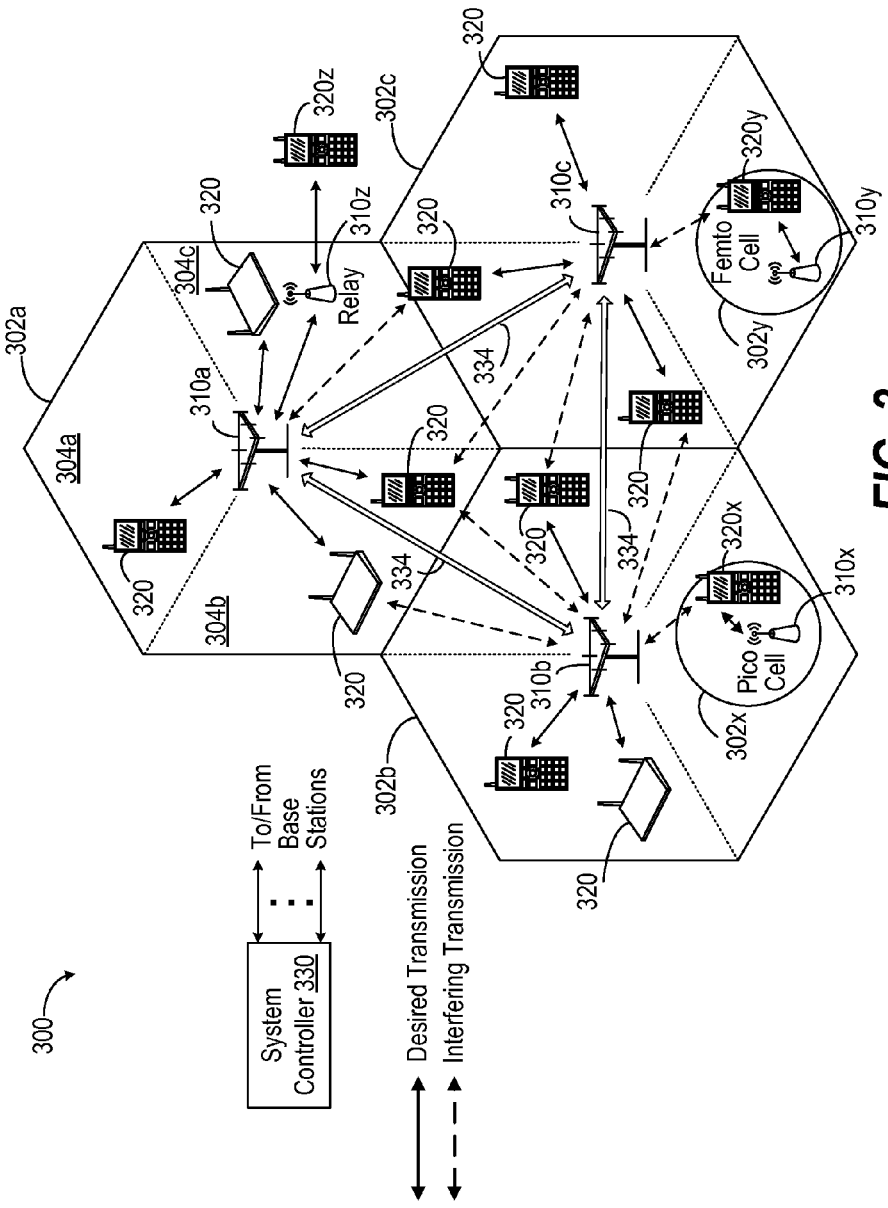

300
System Controller 330
To/From Base Stations
Desired Transmission
Interfering Transmission
302a
302b
302c
302x
302y
304a
304b
304c
310a
310b
310c
310x
310y
310z
320
320x
320y
320z
334
Relay
Femto Cell
Pico Cell

FIG. 3

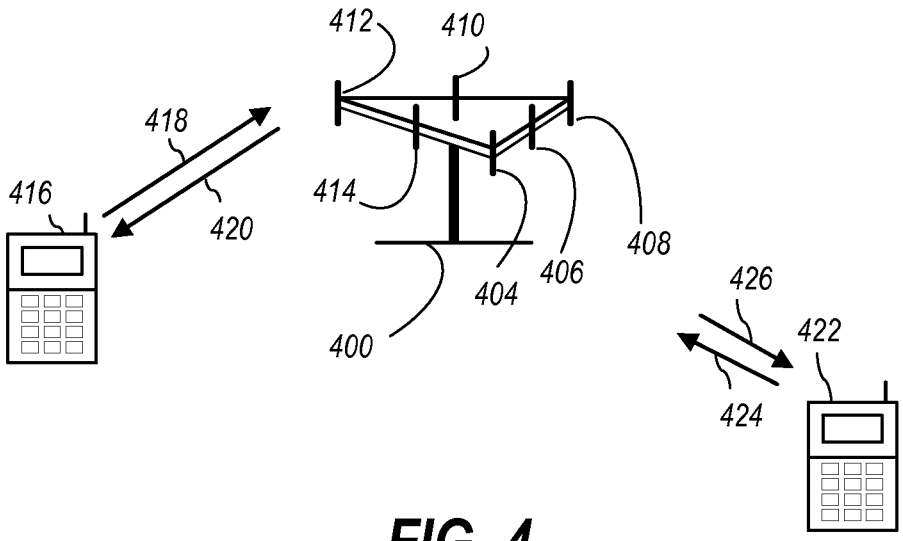


FIG. 4

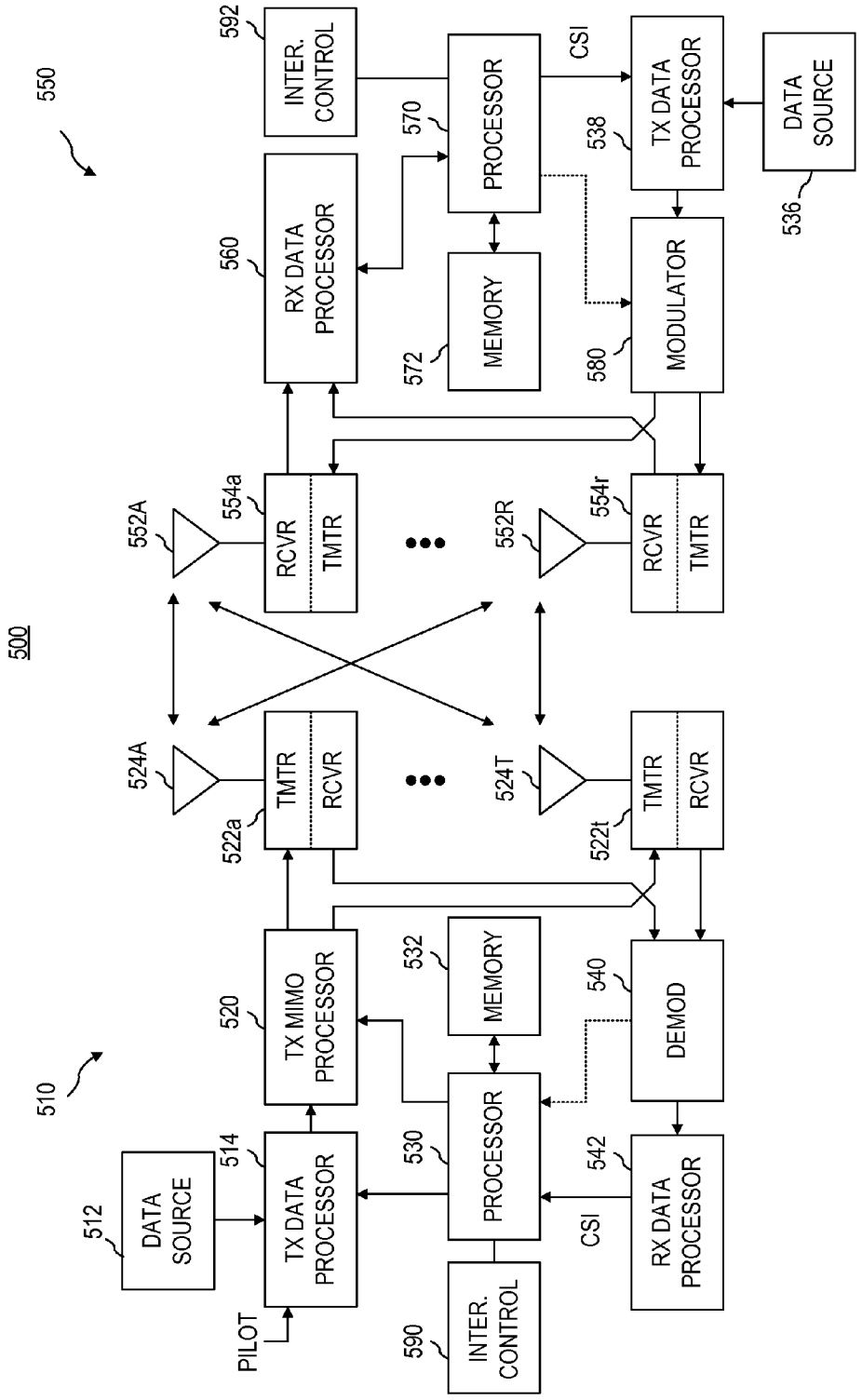

500
510
512
DATA SOURCE
514
TX DATA PROCESSOR
PILOT
520
TX MIMO PROCESSOR
522a
TMTR
RCVR
524A
552A
554a
RCVR
TMTR
530
PROCESSOR
532
MEMORY
590
INTER. CONTROL
540
DEMOD
542
RX DATA PROCESSOR
CSI
522t
TMTR
RCVR
524T
552R
554r
RCVR
TMTR
550
560
RX DATA PROCESSOR
570
PROCESSOR
572
MEMORY
580
MODULATOR
538
TX DATA PROCESSOR
CSI
536
DATA SOURCE
592
INTER. CONTROL

FIG. 5

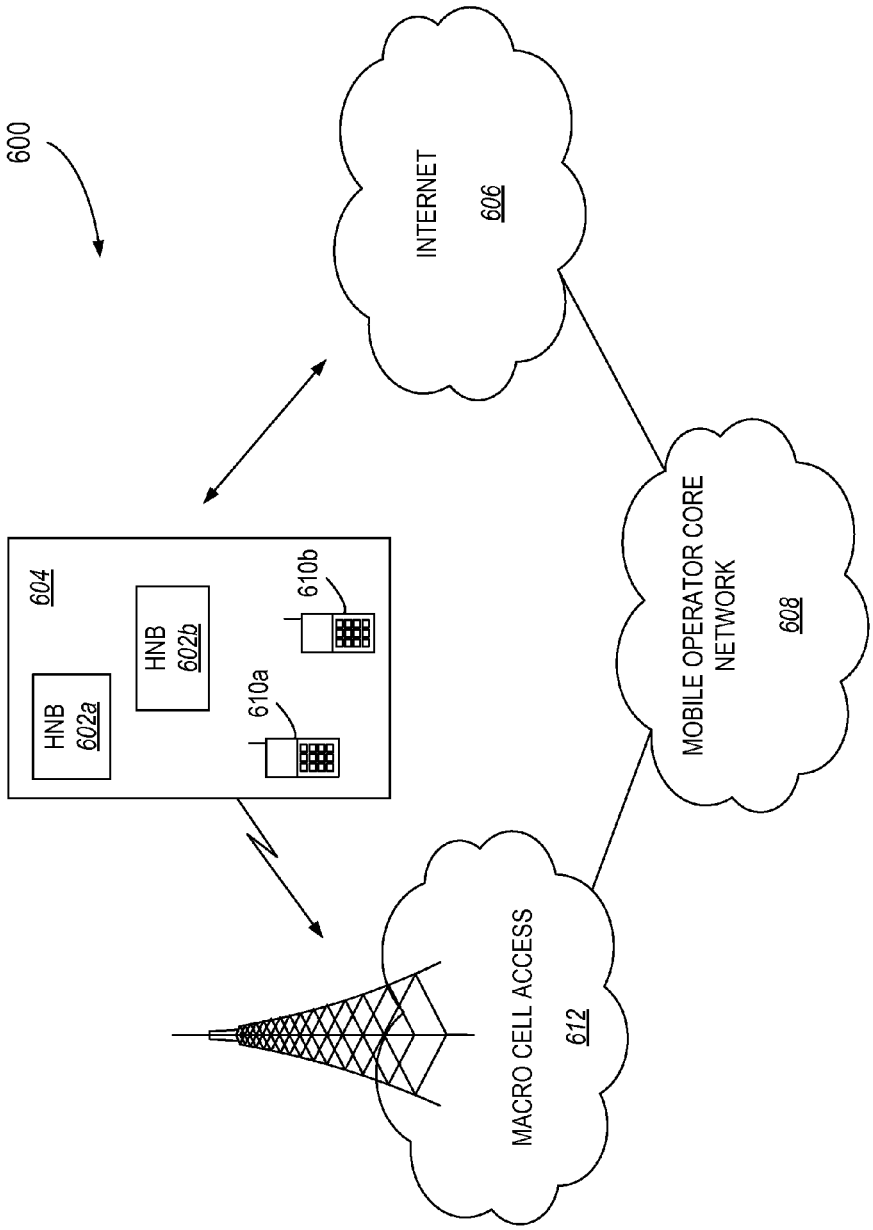

600
INTERNET
606
MOBILE OPERATOR CORE NETWORK
608
MACRO CELL ACCESS
612
604
HNB
602a
HNB
602b
610a
610b

FIG. 6

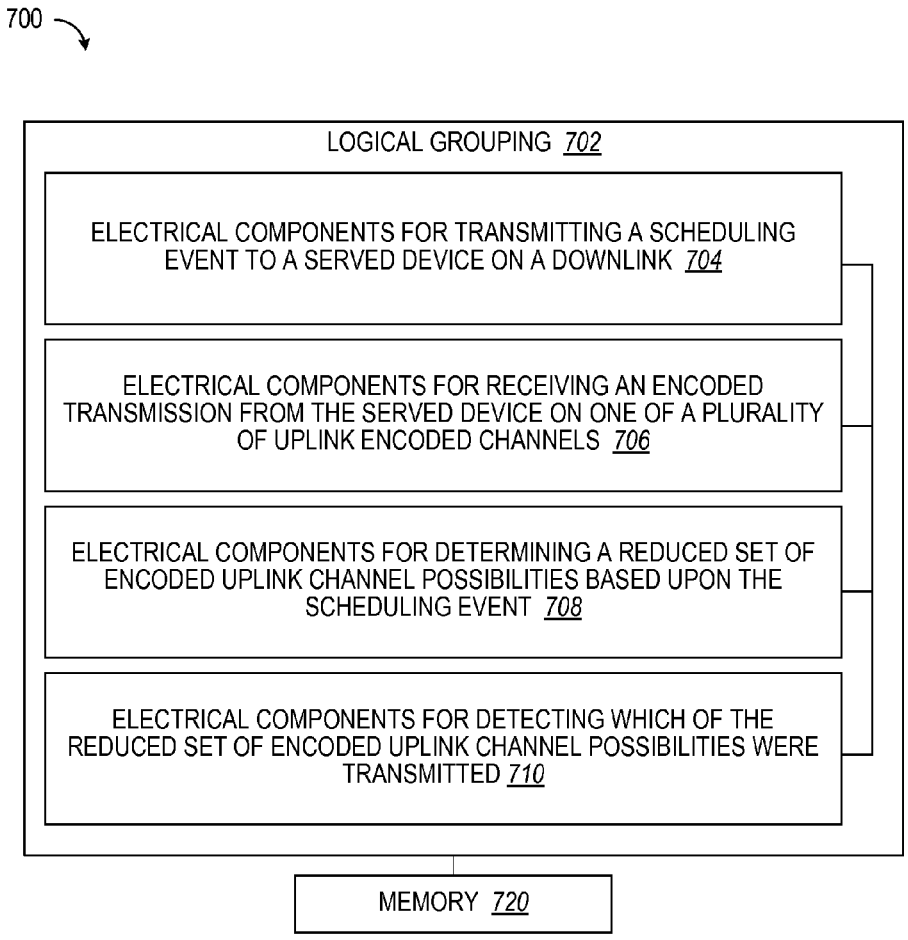

700
LOGICAL GROUPING 702
ELECTRICAL COMPONENTS FOR TRANSMITTING A SCHEDULING EVENT TO A SERVED DEVICE ON A DOWNLINK 704
ELECTRICAL COMPONENTS FOR RECEIVING AN ENCODED TRANSMISSION FROM THE SERVED DEVICE ON ONE OF A PLURALITY OF UPLINK ENCODED CHANNELS 706
ELECTRICAL COMPONENTS FOR DETERMINING A REDUCED SET OF ENCODED UPLINK CHANNEL POSSIBILITIES BASED UPON THE SCHEDULING EVENT 708
ELECTRICAL COMPONENTS FOR DETECTING WHICH OF THE REDUCED SET OF ENCODED UPLINK CHANNEL POSSIBILITIES WERE TRANSMITTED 710
MEMORY 720

FIG. 7

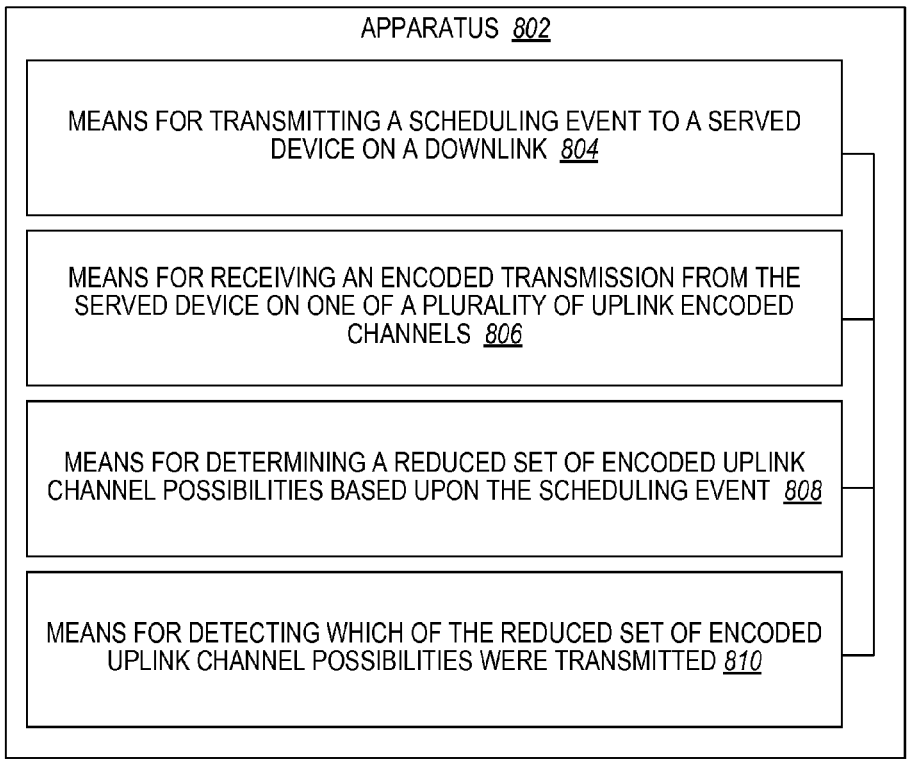

APPARATUS 802
MEANS FOR TRANSMITTING A SCHEDULING EVENT TO A SERVED DEVICE ON A DOWNLINK 804
MEANS FOR RECEIVING AN ENCODED TRANSMISSION FROM THE SERVED DEVICE ON ONE OF A PLURALITY OF UPLINK ENCODED CHANNELS 806
MEANS FOR DETERMINING A REDUCED SET OF ENCODED UPLINK CHANNEL POSSIBILITIES BASED UPON THE SCHEDULING EVENT 808
MEANS FOR DETECTING WHICH OF THE REDUCED SET OF ENCODED UPLINK CHANNEL POSSIBILITIES WERE TRANSMITTED 810

FIG. 8

BLIND DECODING OF UPLINK CONTROL CHANNELS

BACKGROUND

1. Field

The present disclosure relates generally to communication, and more specifically to techniques for receiving and decoding information in a wireless communication network.

2. Background

Wireless communication systems are widely deployed to provide various types of communication content such as voice, data, and so on. These systems may be multiple access systems capable of supporting communication with multiple users by sharing the available system resources (e.g., bandwidth and transmit power). Examples of such multiple access systems include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, and orthogonal frequency division multiple access (OFDMA) systems.

Generally, a wireless multiple access communication system can simultaneously support communication for multiple wireless terminals. Each terminal communicates with one or more base stations via transmissions on the forward and reverse links. The forward link (or downlink) refers to the communication link from the base stations to the terminals, and the reverse link (or uplink) refers to the communication link from the terminals to the base stations. This communication link may be established via a single-input-single-output (SISO), multiple-input-single-output (MISO), single-input-multiple-output (SIMO) or a multiple-input-multiple-output (MIMO) system.

Universal Mobile Telecommunications System (UMTS) is one of the third-generation (3G) cell phone technologies. UTRAN, short for UMTS Terrestrial Radio Access Network, is a collective term for the base nodes (Node B's) and Radio Network Controllers (RNC) which make up the UMTS core network. This communications network can carry many traffic types, from real-time Circuit Switched to IP based Packet Switched. The UTRAN allows connectivity between the UE (user equipment) and the core network. The UTRAN contains the base stations, which are called Node Bs, and RNCs. The RNC provides control functionalities for one or more Node Bs. A Node B and an RNC can be the same device, although typical implementations have a separate RNC located in a central office serving multiple Node B's. Despite the fact that they do not have to be physically separated, there is a logical interface between them known as the Iub. The RNC and its corresponding Node Bs are called the Radio Network Subsystem (RNS). There can be more than one RNS present in an UTRAN.

Third Generation Partnership Project (3GPP) LTE (Long Term Evolution) is the name given to a project within the 3GPP to improve the UMTS mobile phone standard to cope with future requirements. Goals include improving efficiency, lowering costs, improving services, making use of a new spectrum of opportunities, and better integration with other open standards. The LTE system is described in the Evolved UTRA (EUTRA) and Evolved UTRAN (EUTRAN) series of specifications. In order to provide improved communication services and increased efficiency, cellular communication systems are continuously developed and enhanced. Currently, the 3rd Generation Partnership Project (3GPP) standards body is in the process of standardizing improvements to the Universal Mobile Telecommunication System (UMTS) known as LTE.

Similarly, to advanced communication services, such as High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), LTE uses a very fast scheduling of communication resources allocated to user traffic and control data over the air interface. Specifically, scheduling for user traffic may be performed in the individual serving base station (eNodeB) thereby allowing scheduling to be so fast that it can follow changes in the characteristics of the propagation channels to the individual User Equipments (UEs). This is used to schedule data for UEs such that data is predominantly scheduled for UEs which currently experience advantageous propagation conditions. The fast scheduling may be performed both for uplink user data traffic transmitted on a physical channel known as the Physical Uplink Shared CHannel (PUSCH) and for downlink user data traffic transmitted on a physical channel known as the Physical Downlink Shared CHannel (PDSCH).

In LTE, the resource allocation can be changed in subframes having a duration of only 1 ms with a typical scheduling interval (i.e. how often the scheduling algorithm runs) of between 1 and 10 sub-frames. One frame consists of 10 such consecutive sub-frames. The PUSCH and PDSCH are shared channels wherein the scheduling is not only dependent on the current propagation conditions but also on the resource requirement of the UEs. In order to simplify the scheduling and to reduce the signaling overhead, LTE allows for persistent scheduling wherein a resource allocation for the PUSCH or PDSCH may be made for a plurality of subframes.

In order to provide efficient fast scheduling in the base station, the UE must transmit uplink control information to the scheduling base station. Specifically, the UE transmits Channel Quality Indicator (CQI) data which is indicative of the current propagation conditions for the UE. Based on the measurements of the received signal, the UE generates a CQI which may indicate a modulation scheme and data rate that is considered to be supportable by the air interface communication channel from the base station to the UE, or which may be a measure of the Signal to Noise plus Interference Ratio. As another example, LTE uses a retransmission scheme (referred to as Automatic Repeat reQuest (ARQ) or Hybrid ARQ (HARD)) and the UE transmits ARQ data in the form of uplink acknowledge (ACK) or non-acknowledge (NACK) messages which are used to determine whether individual data packets need to be retransmitted. As yet another example, LTE allows the base station to utilize adaptive antenna technology and the UE may report a Precoding Matrix Index (PMI) which is used to signal the antenna weights recommended by the UE for the individual antenna elements.

The uplink control information is transmitted using physical uplink channels. Specifically, in sub-frames wherein the UE transmits uplink user data traffic on the PUSCH, the control data is embedded within the transmission such that the control information is transmitted to the base station using the PUSCH. However, for sub-frames wherein no uplink user data traffic is transmitted on the PUSCH, the UE uses a physical uplink channel known as the Physical Uplink Control CHannel (PUCCH) to transmit the control information. Thus, the physical air interface channel used for the transmission of the control information may change for different sub-frames.

SUMMARY

The following presents a simplified summary in order to provide a basic understanding of some aspects of the disclosed aspects. This summary is not an extensive overview

and is intended to neither identify key or critical elements nor delineate the scope of such aspects. Its purpose is to present some concepts of the described features in a simplified form as a prelude to the more detailed description that is presented later.

In one aspect, a method is provided for facilitating decoding across multiple channels in a wireless communication system by employing a processor executing computer executable instructions stored on a computer readable storage medium to implement the following acts: A scheduling event is transmitted to a served device on a downlink. An encoded transmission is received from the served device on one of a plurality of uplink encoded channels. A reduced set of encoded uplink channel possibilities is determined based upon the scheduling event. Which of the reduced set of encoded uplink channel possibilities were transmitted is detected.

In another aspect, a computer program product is provided for facilitating decoding across multiple channels in a wireless communication system. At least one computer readable storage medium stores computer executable instructions that, when executed by at least one processor, implement components. A component is for transmitting a scheduling event to a served device on a downlink. A component is for receiving an encoded transmission from the served device on one of a plurality of uplink encoded channels. A component is for determining a reduced set of encoded uplink channel possibilities based upon the scheduling event. A component is for detecting which of the reduced set of encoded uplink channel possibilities were transmitted.

In an additional aspect, an apparatus is provided for facilitating decoding across multiple channels in a wireless communication system. At least one computer readable storage medium stores computer executable instructions that, when executed by at least one processor, implement components. Means are provided for transmitting a scheduling event to a served device on a downlink. Means are provided for receiving an encoded transmission from the served device on one of a plurality of uplink encoded channels. Means are provided for determining a reduced set of encoded uplink channel possibilities based upon the scheduling event. Means are provided for detecting which of the reduced set of encoded uplink channel possibilities were transmitted.

In a further aspect, an apparatus is provided for facilitating decoding across multiple channels in a wireless communication system. A processor is operatively coupled to a computer readable storage medium having stored thereon the following computer executable components: A transmitter is for transmitting a scheduling event to a served device on a downlink. A receiver is for receiving an encoded transmission from the served device on one of a plurality of uplink encoded channels. A computing platform is for determining a reduced set of encoded uplink channel possibilities based upon the scheduling event. A detector is for detecting which of the reduced set of encoded uplink channel possibilities were transmitted.

To the accomplishment of the foregoing and related ends, one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative aspects and are indicative of but a few of the various ways in which the principles of the aspects may be employed. Other advantages and novel features will become apparent from the following detailed description when considered in conjunction with the drawings, and the disclosed aspects are intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, nature, and advantages of the present disclosure will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. **1** depicts a block diagram of a wireless communication system in which backhaul communication between nodes is used to allocate resources using a jamming graph.

FIGS. **2**A-**2**B depict a flow diagram for a methodology or sequence of operations for facilitating decoding across multiple channels in a wireless communication system.

FIG. **3** depicts a block diagram of base stations serving and interfering with a population of terminals.

FIG. **4** depicts a block diagram of a multiple access wireless communication system.

FIG. **5** depicts a block diagram of a communication system between a base station and a terminal.

FIG. **6** depicts a block diagram of a communication system to enable deployment of access point base stations within a network environment.

FIG. **7** depicts a block diagram for a system containing logical groupings of electrical components for facilitating decoding across multiple channels in a wireless communication system.

FIG. **8** depicts a block diagram for an apparatus having means for facilitating decoding across multiple channels in a wireless communication system.

DETAILED DESCRIPTION

In Third Generation Partnership Project (3GPP) LTE (Long Term Evolution), the uplink ACK (acknowledge) and CQI (channel quality indicator) bits are jointly transmitted in the same resources to maintain a low peak to average ratio (PAR) waveform. Further, when data needs to be transmitted, the uplink control channels are multiplexed with data prior to transmission. However, due to errors on the downlink (DL) and uplink (UL) assignments, an evolved Base Node (eNB) receiver needs to employ a set of rules to decode the control channels and to minimize the number of blind decoding hypotheses. This innovation describes the rules employed by a receiver to reduce complexity and computational overhead, in part by assuming that the UE is responding to grant on the downlink while providing for combinations in which one or more types of grants are not received. Energy detection in accordance with metrics and normalizing for differing power controls enables selecting the correct combination for decoding.

Various aspects are now described with reference to the drawings. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects. It may be evident, however, that the various aspects may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to facilitate describing these aspects.

With reference to FIG. **1**, a communication system **100** has a base station, such as an evolved Base Node (eNB) **102** that schedules an access terminal, depicted as user equipment (UE) **104**, for wireless (i.e., over-the-air) data packet communication. To that end, on Layer 3 (L3) **106** of a downlink (DL) **108**, the eNB **102** can provide a persistent (periodic) grant on an uplink (UL) **110** for reporting channel feedback, depicted as Channel Quality Indication (CQI) scheduling **112**.

An L2 layer (e.g., Physical Downlink Control Channel (PDCCH) **114** can be used to send a DL grant **116** requiring the UE **104** to receive data from the eNB **102**. Another scheduling event can be an UL grant **118** for the UE **104** to transmit data **120** on the UL **110**, which in an exemplary aspect is on a Physical Uplink Shared Channel (PUSCH) **122**. In some instances a persistent UL grant **124** is provided via L2 (PDCCH) **114** wherein the UE **104** can transmit persistent data **126** on PUSCH **122**. Alternative to L3 persistent CQI scheduling **112**, the eNB **102** can also use the L2 (PDCCH) **114** to request the UE to transmit an aperiodic CQI channel feedback grant.

The UE **104** is expected to acknowledge (ACK) **130** receipt of the data on the downlink as scheduled by DL grant **116**. The UE **104** transmits either aperiodic or periodic CQI **132** based on L2 grant from eNB (PDCCH) **114**. If the UE **104** has only control to transmit, either Ack **130** and/or CQI **132**, then Physical Uplink Control Channel (PUCCH) **134** is used. As previously mentioned, PUSCH **122** is used for data **120**, **126**, which can entail multiplexing Ack **136** and/or CQI **138** if also supposed to be transmitted with data **120**, **126**.

There are several ways of multiplexing control (e.g., ACK and CQI) and data. One approach would be that PUCCH **134** resources are allocated to all UEs requesting resource of the PUSCH **122** such that a physical channel is available for transmission of CQI data even if no user data is transmitted on the PUSCH **122**. However, LTE uses a Single Carrier Frequency Division Multiple Access (SC-FDMA) modulation scheme which requires all uplink transmissions to use a contiguous set of subcarriers as depicted at **140**. As the PUCCH **134** is assigned to subcarriers towards the upper and lower end of the available subcarriers and the PUSCH **134** may be allocated to subcarriers which are not adjacent to the PUCCH subcarriers, it is typically not possible to have simultaneous PUSCH **122** and PUCCH **134** transmissions. Accordingly, uplink control data is transmitted together with user data on the PUSCH **122** if there is such a transmission in the subframe and is transmitted on the PUCCH **134** otherwise.

The eNB **102** can be expected to decode eight different scenarios with regard to whether an Ack, CQI or data has been prompted by a scheduling event(s) on the downlink **108**. In particular, in order to address the possible combination of data and control, the UE transmits on certain resources as depicted in TABLE 1:

TABLE 1

Scenario	Ack	CQI	Data	Resources Used
1	No	No	Yes	Data
2	Yes	No	Yes	Data
3	No	Yes	Yes	Data
4	Yes	Yes	Yes	Data
5	No	No	No	—
6	Yes	No	No	ACK
7	No	Yes	No	CQI
8	Yes	Yes	No	CQI

These are depicted in the time/frequency representation **140** as CQI (either aperiodic or periodic) **142**, Ack **144** and Ack+CQI **146** on PUCCH **134** and by data **148**, persistent data **150**, data+Ack **152**, data+CQI **154**, data+Ack+CQI **156** on PUSCH **122**.

However, such an approach can have a number of disadvantages. For example, the PUCCH resource tends to be limited but is reserved even in situations where it is not actively used. Also, as the uplink data and control may be transmitted on two different physical channels, the eNB **102** typically decodes both channels **122**, **134**. This results in increased latency of the decoding of the uplink control data and increases the complexity and computational demand of the base station.

Advantageously, the eNB **102** benefits from the information from a scheduling event component **160** that knows what uplink transmissions were prompted. In some instances, pathloss, interference, etc., as depicted at **162** causes the UE **104** to miss a scheduling event. The eNB **102** can benefit from a reduced set computing platform **164** that makes a guiding assumption that the UE **104** will not provide a response (i.e., data, Ack, CQI) on the uplink **110** without a corresponding prompting on the downlink **108**. This reduces the set of possibilities (e.g., hypotheses) for what needs to be blind decoded. For robustness, the reduced set also contemplates that a grant was missed by the UE **104**. With the reduced set determined for a particular time frame, an energy detector **166** determines whether a particular response is present in the uplink transmission from the UE **104**. Since the two channels have separate power control, a channel metrics/normalizer component **168** assists in comparing the detected possibilities for determining the probable correct combination. Then an uplink demodulation/decoder **170** can utilize the information in the confirmed correct combination.

In FIGS. **2A-2B**, a methodology or sequence of operations **200** is provided for facilitating decoding across multiple channels in a wireless communication system. A scheduling event is transmitted from an eNB to a served device (e.g., user equipment (UE)) on a downlink (block **202**). In particular, the scheduling event can be as one or more of a group consisting of an uplink data grant (block **204**), a downlink grant (block **206**), and an uplink channel feedback grant (block **208**). In an exemplary implementation, when the UE has control only to transmit on the uplink, the UE uses PUCCH (block **210**). When the UE has data to send with or without control, the latter including Ack and/or Channel Quality Indicator (CQI)), the UE transmits on the PUSCH (block **212**).

In some instances, the uplink data grant of block **204** is a persistent grant that allows the served device to transmit on the first interval of the frame for multiple frames (block **214**). In addition, in some instances the uplink channel feedback grant (e.g., CQI) can be periodic rather than dynamic (block **216**). For instance, periodic configuration can be achieved on L3 layer of the downlink. The CQI can be scheduled as part of a resource block (RB) with a cyclic shift based upon the L3 configuration (block **218**).

Responding to a downlink scheduling grant of block **206**, the UE is expected to acknowledge (ACK) if successfully received or to affirmatively indicate unsuccessful receipt (Nack) if the UE recognizes the transmission. Thus, the Ack is an aperiodic response that is dependent upon whether the downlink is scheduled or not and is scheduled by either L2 layer (Physical Downlink Control Channel (PDCCH)) or L3 (persistent) based (block **220**). In an exemplary implementation, the ACK is transmitted on the uplink as part of a resource block (RB) with a cyclic shift and time domain spreading code, and implicitly mapped based upon a PDCCH or downlink virtual resource block (VRB) index (block **222**).

In some instances, the scheduling event is appropriately responded to by both CQI and Ack. This combined control response is aperiodic, dependent upon whether ACK is to be transmitted or not along with a CQI. In an exemplary implementation, the CQI+Ack are transmitted by resource block (RB) with cyclic shift based upon CQI configuration (block **223**).

With further reference back at block **212**, data to transmit on PUSCH is aperiodic dependent upon whether uplink is

scheduled or not on either L2 layer (PDCCH) or L3 layer (persistent) based (block **224**). If control is to accompany data, then the data in addition to control Ack, CQI, or both is multiplexed prior to Discrete Fourier Transform (DFT) (block **226**). Then, the data only, or the data multiplexed with control (Ack and/or CQI) as applicable, is transmitted on the PUSCH (block **212**).

Advantageously, the receiving entity (e.g., eNB) can reduce the number of blind decoding attempts, thereby reducing device complexity and computational overhead (block **228**). For a large number of served devices, this enhanced efficiency can enable expanded service or Quality of Service (QoS). Thus, the eNB need not look for each of the eight scenarios of TABLE 1: acknowledgement (ACK), channel feedback (e.g., CQI), data, data encoded with Ack, data encoded with channel feedback, and data encoded with both Ack and channel feedback, channel feedback and Ack, or none at all (block **230**). In order to be robust, it is assumed that the served device can respond or fail to respond to a downlink scheduling event (block **232**). In order to achieve a reduced set of possibilities, it is assumed that the served device will not respond with data, CQI or Ack unless there was a corresponding scheduling event transmitted on the downlink to prompt such a reply (block **234**). The corresponding scheduling event can be substantially earlier for persistent or periodic scheduling (block **236**). The reduced set also incorporates an assumption that control, if present, will comply with the downlink signaled configuration (e.g., 1- or 2-bit CQI, 8-bit CQI) It should be appreciated that twenty (20) coded bits are available on Channel Quality Indicator Channel (CQICH).

The eNB detects which of the reduced set of possibilities was transmitted on the UL (block **238**). The detection can be by energy detection on PUSCH if in the reduced set from demodulation reference signals (RS) (block **240**); energy detection on PUSCH from data and demodulation reference signals (RS) (block **242**); or energy detection on PUSCH by non-coherent accumulation (block **244**).

The detection can further include demultiplexing control from the data if applicable to the reduced set by demodulating reference signals and CQI (block **246**).

Alternatively or in addition, energy detection on PUCCH if in the reduced set can include determining channel quality indication (CQI) present in a sub-frame, wherein frequency domain de-spreading of PUCCH occurs prior to energy detection (block **248**).

The energy detection on the PUCCH and PUSCH can compensate for differing transmission power control (block **250**). In one example, scaling of energy detection values are made with respect to power spectral density (PSD) offsets (block **252**). In another example, a relative metric can be used for PUSCH versus PUCCH (block **254**). In an additional example, an absolute metric can be used for PUSCH versus PUCCH (block **256**).

In some aspects the teachings herein may be employed in a network that includes macro scale coverage (e.g., a large area cellular network such as a 3G (Third Generation) network, typically referred to as a macro cell network) and smaller scale coverage (e.g., a residence-based or building-based network environment). As an access terminal ("AT") moves through such a network, the access terminal may be served in certain locations by access nodes ("ANs") that provide macro coverage while the access terminal may be served at other locations by access nodes that provide smaller scale coverage. In some aspects, the smaller coverage nodes may be used to provide incremental capacity growth, in-building coverage, and different services (e.g., for a more robust user experience). In the discussion herein, a node that provides coverage over a relatively large area may be referred to as a macro node. A node that provides coverage over a relatively small area (e.g., a residence) may be referred to as a femto node. A node that provides coverage over an area that is smaller than a macro area and larger than a femto area may be referred to as a pico node (e.g., providing coverage within a commercial building).

A cell associated with a macro node, a femto node, or a pico node may be referred to as a macro cell, a femto cell, or a pico cell, respectively. In some implementations, each cell may be further associated with (e.g., divided into) one or more sectors.

In various applications, other terminology may be used to reference a macro node, a femto node, or a pico node. For example, a macro node may be configured or referred to as an access node, base station, access point, eNodeB, macro cell, and so on. Also, a femto node may be configured or referred to as a Home NodeB, Home eNodeB, access point base station, femto cell, and so on.

In the example shown in FIG. **3**, base stations **310***a*, **310***b* and **310***c* may be macro base stations for macro cells **302***a*, **302***b* and **302***c*, respectively. Base station **310***x* may be a pico base station for a pico cell **302***x* communicating with terminal **320***x*. Base station **310***y* may be a femto base station for a femto cell **302***y* communicating with terminal **320***y*. Although not shown in FIG. **3** for simplicity, the macro cells may overlap at the edges. The pico and femto cells may be located within the macro cells (as shown in FIG. **3**) or may overlap with macro cells and/or other cells.

Wireless network **300** may also include relay stations, e.g., a relay station **310***z* that communicates with terminal **320***z*. A relay station is a station that receives a transmission of data and/or other information from an upstream station and sends a transmission of the data and/or other information to a downstream station. The upstream station may be a base station, another relay station, or a terminal. The downstream station may be a terminal, another relay station, or a base station. A relay station may also be a terminal that relays transmissions for other terminals. A relay station may transmit and/or receive low reuse preambles. For example, a relay station may transmit a low reuse preamble in a similar manner as a pico base station and may receive low reuse preambles in similar manner as a terminal.

A network controller **330** may couple to a set of base stations and provide coordination and control for these base stations. Network controller **330** may be a single network entity or a collection of network entities. Network controller **330** may communicate with base stations **310** via a backhaul. Backhaul network communication **334** can facilitate point-to-point communication between base stations **310***a*-**310***c* employing such a distributed architecture. Base stations **310***a*-**310***c* may also communicate with one another, e.g., directly or indirectly via wireless or wireline backhaul.

Wireless network **300** may be a homogeneous network that includes only macro base stations (not shown in FIG. **3**). Wireless network **300** may also be a heterogeneous network that includes base stations of different types, e.g., macro base stations, pico base stations, home base stations, relay stations, etc. These different types of base stations may have different transmit power levels, different coverage areas, and different impact on interference in wireless network **300**. For example, macro base stations may have a high transmit power level (e.g., 20 Watts) whereas pico and femto base stations may have a low transmit power level (e.g., 9 Watt). The techniques described herein may be used for homogeneous and heterogeneous networks.

Terminals **320** may be dispersed throughout wireless network **300**, and each terminal may be stationary or mobile. A terminal may also be referred to as an access terminal (AT), a mobile station (MS), user equipment (UE), a subscriber unit, a station, etc. A terminal may be a cellular phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, etc. A terminal may communicate with a base station via the downlink and uplink. The downlink (or forward link) refers to the communication link from the base station to the terminal, and the uplink (or reverse link) refers to the communication link from the terminal to the base station.

A terminal may be able to communicate with macro base stations, pico base stations, femto base stations, and/or other types of base stations. In FIG. **3**, a solid line with double arrows indicates desired transmissions between a terminal and a serving base station, which is a base station designated to serve the terminal on the downlink and/or uplink. A dashed line with double arrows indicates interfering transmissions between a terminal and a base station. An interfering base station is a base station causing interference to a terminal on the downlink and/or observing interference from the terminal on the uplink.

Wireless network **300** may support synchronous or asynchronous operation. For synchronous operation, the base stations may have the same frame timing, and transmissions from different base stations may be aligned in time. For asynchronous operation, the base stations may have different frame timing, and transmissions from different base stations may not be aligned in time. Asynchronous operation may be more common for pico and femto base stations, which may be deployed indoors and may not have access to a synchronizing source such as a Global Positioning System (GPS).

In one aspect, to improve system capacity, the coverage area **302***a*, **302***b*, or **302***c* corresponding to a respective base station **310***a*-**310***c* can be partitioned into multiple smaller areas (e.g., areas **304***a*, **304***b*, and **304***c*). Each of the smaller areas **304***a*, **304***b*, and **304***c* can be served by a respective base transceiver subsystem (BTS, not shown). As used herein and generally in the art, the term "sector" can refer to a BTS and/or its coverage area depending on the context in which the term is used. In one example, sectors **304***a*, **304***b*, **304***c* in a cell **302***a*, **302***b*, **302***c* can be formed by groups of antennas (not shown) at base station **310**, where each group of antennas is responsible for communication with terminals **320** in a portion of the cell **302***a*, **302***b*, or **302***c*. For example, a base station **310** serving cell **302***a* can have a first antenna group corresponding to sector **304***a*, a second antenna group corresponding to sector **304***b*, and a third antenna group corresponding to sector **304***c*. However, it should be appreciated that the various aspects disclosed herein can be used in a system having sectorized and/or unsectorized cells. Further, it should be appreciated that all suitable wireless communication networks having any number of sectorized and/or unsectorized cells are intended to fall within the scope of the hereto appended claims. For simplicity, the term "base station" as used herein can refer both to a station that serves a sector as well as a station that serves a cell. It should be appreciated that as used herein, a downlink sector in a disjoint link scenario is a neighbor sector. While the following description generally relates to a system in which each terminal communicates with one serving access point for simplicity, it should be appreciated that terminals can communicate with any number of serving access points.

In some aspects, a restricted femto node (which may also be referred to as a Closed Subscriber Group Home NodeB) is one that provides service to a restricted provisioned set of access terminals. This set may be temporarily or permanently extended as necessary. In some aspects, a Closed Subscriber Group ("CSG") may be defined as the set of access nodes (e.g., femto nodes) that share a common access control list of access terminals. A channel on which all femto nodes (or all restricted femto nodes) in a region operate may be referred to as a femto channel.

Various relationships may thus exist between a given femto node and a given access terminal or user equipment. For example, from the perspective of an access terminal, an open femto node may refer to a femto node with no restricted association. A restricted femto node may refer to a femto node that is restricted in some manner (e.g., restricted for association and/or registration). A home femto node may refer to a femto node on which the access terminal is authorized to access and operate on. A guest femto node may refer to a femto node on which an access terminal is temporarily authorized to access or operate on. An alien femto node may refer to a femto node on which the access terminal is not authorized to access or operate on, except for perhaps emergency situations (e.g., 911 calls).

From a restricted femto node perspective, a home access terminal may refer to an access terminal that authorized to access the restricted femto node. A guest access terminal may refer to an access terminal with temporary access to the restricted femto node. An alien access terminal may refer to an access terminal that does not have permission to access the restricted femto node, except for perhaps emergency situations, for example, such as 911 calls (e.g., an access terminal that does not have the credentials or permission to register with the restricted femto node).

For convenience, the disclosure herein describes various functionalities in the context of a femto node. It should be appreciated, however, that a pico node may provide the same or similar functionality for a larger coverage area. For example, a pico node may be restricted, a home pico node may be defined for a given access terminal, and so on.

A wireless multiple-access communication system may simultaneously support communication for multiple wireless access terminals. As mentioned above, each terminal may communicate with one or more base stations via transmissions on the forward and reverse links. The forward link (or downlink) refers to the communication link from the base stations to the terminals, and the reverse link (or uplink) refers to the communication link from the terminals to the base stations. This communication link may be established via a single-in-single-out system ("SISO"), a multiple-in-multiple-out ("MIMO") system, or some other type of system.

Referring to FIG. **4**, a multiple access wireless communication system according to one aspect is illustrated. An access point (AP) **400** includes multiple antenna groups, one including **404** and **406**, another including **408** and **410**, and an additional including **412** and **414**. In FIG. **4**, only two antennas are shown for each antenna group, however, more or fewer antennas may be utilized for each antenna group. Access terminal (AT) **416** is in communication with antennas **412** and **414**, where antennas **412** and **414** transmit information to access terminal **416** over forward link **420** and receive information from access terminal **416** over reverse link **418**. Access terminal **422** is in communication with antennas **406** and **408**, where antennas **406** and **408** transmit information to access terminal **422** over forward link **426** and receive information from access terminal **422** over reverse link **424**. In a FDD system, communication links **418**, **420**, **424** and **426**

may use different frequencies for communication. For example, forward link **420** may use a different frequency then that used by reverse link **418**.

Each group of antennas and/or the area in which they are designed to communicate is often referred to as a sector of the access point. In the aspect, antenna groups each are designed to communicate to access terminals in a sector of the areas covered by access point **400**.

In communication over forward links **420** and **426**, the transmitting antennas of access point **400** utilize beamforming in order to improve the signal-to-noise ratio of forward links for the different access terminals **416** and **422**. Also, an access point using beamforming to transmit to access terminals scattered randomly through its coverage causes less interference to access terminals in neighboring cells than an access point transmitting through a single antenna to all of its access terminals.

An access point may be a fixed station used for communicating with the terminals and may also be referred to as an access point, a Node B, or some other terminology. An access terminal may also be called user equipment (UE), a wireless communication device, terminal, or some other terminology.

A MIMO system employs multiple (N_T) transmit antennas and multiple (N_R) receive antennas for data transmission. A MIMO channel formed by the N_T transmit and N_R receive antennas may be decomposed into N_S independent channels, which are also referred to as spatial channels, where $N_S \leq \min\{N_T, N_R\}$. Each of the N_S independent channels corresponds to a dimension. The MIMO system may provide improved performance (e.g., higher throughput and/or greater reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

A MIMO system may support time division duplex ("TDD") and frequency division duplex ("FDD"). In a TDD system, the forward and reverse link transmissions are on the same frequency region so that the reciprocity principle allows the estimation of the forward link channel from the reverse link channel. This enables the access point to extract transmit beam-forming gain on the forward link when multiple antennas are available at the access point.

The teachings herein may be incorporated into a node (e.g., a device) employing various components for communicating with at least one other node. FIG. **5** depicts several sample components that may be employed to facilitate communication between nodes. Specifically, FIG. **5** illustrates a wireless device **510** (e.g., an access point) and a wireless device **550** (e.g., an access terminal) of a MIMO system **500**. At the device **510**, traffic data for a number of data streams is provided from a data source **512** to a transmit ("TX") data processor **514**.

In some aspects, each data stream is transmitted over a respective transmit antenna. The TX data processor **514** formats, codes, and interleaves the traffic data for each data stream based on a particular coding scheme selected for that data stream to provide coded data.

The coded data for each data stream may be multiplexed with pilot data using OFDM techniques. The pilot data is typically a known data pattern that is processed in a known manner and may be used at the receiver system to estimate the channel response. The multiplexed pilot and coded data for each data stream is then modulated (i.e., symbol mapped) based on a particular modulation scheme (e.g., BPSK, QSPK, M-PSK, or M-QAM) selected for that data stream to provide modulation symbols. The data rate, coding, and modulation for each data stream may be determined by instructions performed by a processor **530**. A data memory **532** may store program code, data, and other information used by the processor **530** or other components of the device **510**.

The modulation symbols for all data streams are then provided to a TX MIMO processor **520**, which may further process the modulation symbols (e.g., for OFDM). The TX MIMO processor **520** then provides N_T modulation symbol streams to N_T transceivers ("XCVR") **522***a* through **522***t* that each has a transmitter (TMTR) and receiver (RCVR). In some aspects, the TX MIMO processor **520** applies beam-forming weights to the symbols of the data streams and to the antenna from which the symbol is being transmitted.

Each transceiver **522***a*-**522***t* receives and processes a respective symbol stream to provide one or more analog signals, and further conditions (e.g., amplifies, filters, and upconverts) the analog signals to provide a modulated signal suitable for transmission over the MIMO channel. N_T modulated signals from transceivers **522***a* through **522***t* are then transmitted from N_T antennas **524***a* through **524***t*, respectively.

At the device **550**, the transmitted modulated signals are received by N_R antennas **552***a* through **552***r* and the received signal from each antenna **552***a*-**552***r* is provided to a respective transceiver ("XCVR") **554***a* through **554***r*. Each transceiver **554***a*-**554***r* conditions (e.g., filters, amplifies, and downconverts) a respective received signal, digitizes the conditioned signal to provide samples, and further processes the samples to provide a corresponding "received" symbol stream.

A receive ("RX") data processor **560** then receives and processes the N_R received symbol streams from N_R transceivers **554***a*-**554***r* based on a particular receiver processing technique to provide N_T "detected" symbol streams. The RX data processor **560** then demodulates, deinterleaves, and decodes each detected symbol stream to recover the traffic data for the data stream. The processing by the RX data processor **560** is complementary to that performed by the TX MIMO processor **520** and the TX data processor **514** at the device **510**.

A processor **570** periodically determines which pre-coding matrix to use. The processor **570** formulates a reverse link message comprising a matrix index portion and a rank value portion. A data memory **572** may store program code, data, and other information used by the processor **570** or other components of the device **550**.

The reverse link message may comprise various types of information regarding the communication link and/or the received data stream. The reverse link message is then processed by a TX data processor **538**, which also receives traffic data for a number of data streams from a data source **536**, modulated by a modulator **580**, conditioned by the transceivers **554***a* through **554***r*, and transmitted back to the device **510**.

At the device **510**, the modulated signals from the device **550** are received by the antennas **524***a*-**524***t*, conditioned by the transceivers **522***a*-**522***t*, demodulated by a demodulator ("DEMOD") **540**, and processed by a RX data processor **542** to extract the reverse link message transmitted by the device **550**. The processor **530** then determines which pre-coding matrix to use for determining the beam-forming weights then processes the extracted message.

FIG. **5** also illustrates that the communication components may include one or more components that perform interference control operations. For example, an interference ("INTER.") control component **590** may cooperate with the processor **530** and/or other components of the device **510** to send/receive signals to/from another device (e.g., device **550**). Similarly, an interference control component **592** may cooperate with the processor **570** and/or other components of

the device **550** to send/receive signals to/from another device (e.g., device **510**). It should be appreciated that for each device **510** and **550** the functionality of two or more of the described components may be provided by a single component. For example, a single processing component may provide the functionality of the interference control component **590** and the processor **530** and a single processing component may provide the functionality of the interference control component **592** and the processor **570**.

FIG. **6** illustrates an exemplary communication system **600** where one or more femto nodes are deployed within a network environment. Specifically, the system **600** includes multiple femto nodes, depicted as Home Base Nodes (HNBs) **602***a* and **602***b*, installed in a relatively small scale network environment (e.g., in one or more user residences **604**). Each femto node **602***a*-**602***b* may be coupled to a wide area network **606** (e.g., the Internet) and a mobile operator core network **608** via a DSL router, a cable modem, a wireless link, or other connectivity means (not shown). As will be discussed below, each femto node **602***a*-**602***b* may be configured to serve associated access terminals or user equipment (UE) **610***a* and, optionally, alien access UEs **610***b* (e.g., not a subscriber to a closed subscriber group). In other words, access to femto nodes **602***a*-**602***b* may be restricted whereby a given UE **610***a*-**610***b* may be served by a set of designated (e.g., home) femto node(s) **602***a*-**602***b* but may not be served by any non-designated femto nodes **602***a*-**602***b* (e.g., a neighbor's femto node **602***a*-**602***b*).

The owner of a femto node **602** may subscribe to a mobile service, such as, for example, 3G mobile service, offered through the mobile operator core network **608**. In addition, an access terminal or UE **610***a*-**610***b* may be capable of operating both in macro environments and in smaller scale (e.g., residential) network environments. In other words, depending on the current location of the UE **610***a*-**610***b*, the access terminal **610***a*-**610***b* may be served by an access node or macro base node **612** of the macro cell mobile network **608** or by any one of a set of femto nodes **602** (e.g., the femto nodes **602***a*-**602***b* that reside within a corresponding user residence **604**). For example, when a subscriber is outside his home, he is served by a standard macro access node (e.g., node **612**) and when the subscriber is at home, he is served by a femto node (e.g., node **602***a*-**602***b*). Here, it should be appreciated that a femto node **602***a*-**602***b* may be backward compatible with existing access terminals or UEs **610***a*-**610***b*.

A femto node **602***a*-**602***b* may be deployed on a single frequency or, in the alternative, on multiple frequencies. Depending on the particular configuration, the single frequency or one or more of the multiple frequencies may overlap with one or more frequencies used by a macro node (e.g., node **612**).

In some aspects, an access terminal or UE **610***a*-**610***b* may be configured to connect to a preferred femto node (e.g., the home femto node of the access terminal or UE **610***a*-**610***b*) whenever such connectivity is possible. For example, whenever the access terminal or UE **610***a*-**610***b* is within the user's residence **604**, it may be desired that the access terminal or UE **610***a*-**610***b* communicate only with the home femto node **602***a*-**602***b*.

In some aspects, if the access terminal or UE **610***a*-**610***b* operates within the macro cellular network **608** but is not residing on its most preferred network (e.g., as defined in a preferred roaming list), the access terminal or UE **610***a*-**610***b* may continue to search for the most preferred network (e.g., the preferred femto node **602***a*-**602***b*) using a Better System Reselection ("BSR"), which may involve a periodic scanning of available systems to determine whether better systems are currently available, and subsequent efforts to associate with such preferred systems. With the acquisition entry, the access terminal or UE **610***a*-**610***b* may limit the search for specific band and channel. For example, the search for the most preferred system may be repeated periodically. Upon discovery of a preferred femto node **602***a*-**602***b*, the access terminal **610***a*-**610***b* selects the femto node **602***a*-**602***b* for camping within its coverage area.

A femto node may be restricted in some aspects. For example, a given femto node may only provide certain services to certain access terminals. In deployments with so-called restricted (or closed) association, a given access terminal may only be served by the macro cell mobile network and a defined set of femto nodes (e.g., the femto nodes **602***a*-**602***b* that reside within the corresponding user residence **604**). In some implementations, a node may be restricted to not provide, for at least one node, at least one of: signaling, data access, registration, paging, or service.

With reference to FIG. **7**, illustrated is a system **700** for facilitating decoding across multiple channels in a wireless communication system. For example, system **700** can reside at least partially within a base station. It is to be appreciated that system **700** is represented as including functional blocks, which can be functional blocks that represent functions implemented by a computing platform, processor, software, or combination thereof (e.g., firmware). System **700** includes a logical grouping **702** of electrical components that can act in conjunction. For instance, logical grouping **702** can include an electrical component for transmitting a scheduling event to a served device on a downlink **704**. Moreover, logical grouping **702** can include an electrical component for receiving an encoded transmission from the served device on one of a plurality of uplink encoded channels **706**. Further, logical grouping **702** can include an electrical component for determining a reduced set of encoded uplink channel possibilities based upon the scheduling event **708**. Logical grouping **702** can include an electrical component for detecting which of the reduced set of encoded uplink channel possibilities were transmitted **710**. Additionally, system **700** can include a memory **720** that retains instructions for executing functions associated with electrical components **704**-**710**. While shown as being external to memory **720**, it is to be understood that one or more of electrical components **704**-**710** can exist within memory **720**.

With reference to FIG. **8**, an apparatus **802** is provided for facilitating decoding across multiple channels in a wireless communication system. Means **804** are provided for transmitting a scheduling event to a served device on a downlink. Means **806** are provided for receiving an encoded transmission from the served device on one of a plurality of uplink encoded channels. Means **808** are provided for determining a reduced set of encoded uplink channel possibilities based upon the scheduling event. Means **810** are provided for detecting which of the reduced set of encoded uplink channel possibilities were transmitted.

Those of skill in the art would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

Those of skill would further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware,

computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

As used in this application, the terms "component", "module", "system", and the like are intended to refer to a computer-related entity, either hardware, a combination of hardware and software, software, or software in execution. For example, a component may be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and/or a computer. By way of illustration, both an application running on a server and the server can be a component. One or more components may reside within a process and/or thread of execution and a component may be localized on one computer and/or distributed between two or more computers.

The word "exemplary" is used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs.

Various aspects will be presented in terms of systems that may include a number of components, modules, and the like. It is to be understood and appreciated that the various systems may include additional components, modules, etc. and/or may not include all of the components, modules, etc. discussed in connection with the figures. A combination of these approaches may also be used. The various aspects disclosed herein can be performed on electrical devices including devices that utilize touch screen display technologies and/or mouse-and-keyboard type interfaces. Examples of such devices include computers (desktop and mobile), smart phones, personal digital assistants (PDAs), and other electronic devices both wired and wireless.

In addition, the various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

Furthermore, the one or more versions may be implemented as a method, apparatus, or article of manufacture using standard programming and/or engineering techniques to produce software, firmware, hardware, or any combination thereof to control a computer to implement the disclosed aspects. The term "article of manufacture" (or alternatively, "computer program product") as used herein is intended to encompass a computer program accessible from any computer-readable device, carrier, or media. For example, computer readable media can include but are not limited to magnetic storage devices (e.g., hard disk, floppy disk, magnetic strips . . .), optical disks (e.g., compact disk (CD), digital versatile disk (DVD) . . .), smart cards, and flash memory devices (e.g., card, stick). Additionally it should be appreciated that a carrier wave can be employed to carry computer-readable electronic data such as those used in transmitting and receiving electronic mail or in accessing a network such as the Internet or a local area network (LAN). Of course, those skilled in the art will recognize many modifications may be made to this configuration without departing from the scope of the disclosed aspects.

The steps of a method or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present disclosure. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the disclosure. Thus, the present disclosure is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

In view of the exemplary systems described supra, methodologies that may be implemented in accordance with the disclosed subject matter have been described with reference to several flow diagrams. While for purposes of simplicity of explanation, the methodologies are shown and described as a series of blocks, it is to be understood and appreciated that the claimed subject matter is not limited by the order of the blocks, as some blocks may occur in different orders and/or concurrently with other blocks from what is depicted and described herein. Moreover, not all illustrated blocks may be required to implement the methodologies described herein. Additionally, it should be further appreciated that the methodologies disclosed herein are capable of being stored on an article of manufacture to facilitate transporting and transferring such methodologies to computers. The term article of manufacture, as used herein, is intended to encompass a computer program accessible from any computer-readable device, carrier, or media.

It should be appreciated that any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated material does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material

set forth herein, will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

What is claimed is:

1. A method for facilitating decoding across multiple channels in a wireless communication system, comprising:

transmitting a scheduling event to a served device on a downlink;

receiving an encoded transmission from the served device on an encoded uplink channel, the encoded uplink channel being a control channel when the encoded transmission only includes control information;

determining a plurality of possible encoded uplink channels based upon the scheduling event, the plurality of possible encoded uplink channels being less than a total number of possible encoded uplink channels; and

detecting the encoded uplink channel from the plurality of possible encoded uplink channels based at least in part on energy detection of the encoded uplink channel.

2. The method of claim **1**, wherein determining the plurality of possible encoded uplink channels comprises:

determining each combination of possible responses comprising one or more of an acknowledgement (ACK), a channel quality indicator (CQI), data, the data encoded with the ACK, the data encoded with the CQI, the data encoded with both the ACK and the CQI, or a combination thereof; and

reducing a set of combinations by obviating any combination having a transmission that is not responsive to the scheduling event.

3. The method of claim **1**, further comprising transmitting the scheduling event as one or more of an uplink data grant, a downlink grant, an uplink channel feedback grant, or a combination thereof.

4. The method of claim **3**, wherein the scheduling event further consists of a persistent uplink data grant.

5. The method of claim **3**, further comprising:

transmitting the scheduling event as a combination of an uplink data grant, a downlink grant, and an uplink channel feedback grant; and

determining the plurality of possible encoded uplink channels based upon the scheduling event by assuming that the served device responds to at least one scheduling event and does not respond to a combination of scheduling events that were not transmitted; and

wherein detecting the encoded uplink channel from the plurality of possible encoded uplink channels comprises:

detecting uplink data on a first uplink channel;

detecting uplink data multiplexed with acknowledgement, channel feedback, or both on the first uplink channel; and

detecting uplink channel feedback on a second uplink channel.

6. The method of claim **5**, wherein the uplink channel feedback grant on the second uplink channel comprises a periodic grant.

7. The method of claim **5**, wherein uplink data comprises data in response to a persistent grant.

8. The method of claim **1**, further comprising:

transmitting the scheduling event of an uplink data grant, a downlink grant, or an uplink channel feedback grant;

determining the plurality of possible encoded uplink channels based at least in part upon the scheduling event by assuming that the served device responds to at least one scheduling event; and

detecting uplink data on a first uplink channel;

detecting uplink data multiplexed with one or more of an acknowledgement, channel feedback, or a combination thereof on the first uplink channel; or

detecting uplink channel feedback on a second uplink channel.

9. The method of claim **8**, wherein the uplink data grant comprises a persistent grant.

10. The method of claim **8**, wherein the uplink channel feedback grant comprises a periodic grant.

11. The method of claim **1**, wherein the energy detection is performed on a Physical Uplink Control Channel (PUCCH) and a Physical Uplink Shared Channel (PUSCH).

12. The method of claim **11**, further comprising performing energy detection on the PUSCH based on demodulation reference signals.

13. The method of claim **11**, further comprising performing energy detection on the PUSCH based on data and demodulation reference signals (RS).

14. The method of claim **11**, further comprising performing energy detection on the PUSCH by non-coherent accumulation.

15. The method of claim **11**, further comprising performing energy detection on the PUCCH in response to determining channel quality indicator (CQI) present in a sub-frame, wherein frequency domain de-spreading of the PUCCH occurs prior to energy detection.

16. The method of claim **11**, further comprising performing energy detection on the PUSCH based on demodulation reference signals and channel quality indicator (CQI).

17. The method of claim **11**, further comprising normalizing energy detection on the PUCCH and the PUSCH for compensating for differing transmission power control.

18. The method of claim **17**, further comprising scaling energy detection values with respect to power spectral density offsets.

19. The method of claim **17**, further comprising using a relative metric for the PUSCH in comparison to the PUCCH.

20. The method of claim **17**, further comprising using an absolute metric for the PUSCH in comparison to the PUCCH.

21. A computer program product for facilitating decoding across multiple channels in a wireless communication system, the computer program product comprising:

a non-transitory computer-readable medium having program code recorded thereon, the program code comprising:

program code to transmit a scheduling event to a served device on a downlink;

program code to receive an encoded transmission from the served device on an encoded uplink channel, the encoded uplink channel being a control channel when the encoded transmission only includes control information;

program code to determine a plurality of possible encoded uplink channels based upon the scheduling event, the plurality of possible encoded uplink channels being less than a total number of possible encoded uplink channels; and

program code to detect the encoded uplink channel from the plurality of possible encoded uplink channels based at least in part on energy detection of the encoded uplink channel.

22. An apparatus for facilitating decoding across multiple channels in a wireless communication system, comprising:

means for transmitting a scheduling event to a served device on a downlink;

means for receiving an encoded transmission from the served device on an encoded uplink channel, the

encoded uplink channel being a control channel when the encoded transmission only includes control information;

means for determining a plurality of possible encoded uplink channels based upon the scheduling event, the plurality of possible encoded uplink channels being less than a total number of possible encoded uplink channels; and

means for detecting the encoded uplink channel from the plurality of possible encoded uplink channels based at least in part on energy detection of the encoded uplink channel.

23. An apparatus for facilitating decoding across multiple channels in a wireless communication system, comprising:

a memory unit; and

at least one processor coupled to the memory unit, the at least one processor being configured:

to transmit a scheduling event to a served device on a downlink;

to receive an encoded transmission from the served device on an encoded uplink channel, the encoded uplink channel being a control channel when the encoded transmission only includes control information;

to determine a plurality of possible encoded uplink channels based upon the scheduling event, the plurality of possible encoded uplink channels being less than a total number of possible encoded uplink channels; and

to detect the encoded uplink channel from the plurality of possible encoded uplink channels based at least in part on energy detection of the encoded uplink channel.

24. The apparatus of claim **23**, wherein the at least one processor is further configured:

to determine each combination of possible responses comprising one or more of an acknowledgement (ACK), a channel quality indicator (CQI), data, the data encoded with the ACK, the data encoded with the CQI, the data encoded with both the ACK and the CQI, or a combination thereof; and

to reduce a set of combinations by obviating any combination having a transmission that is not responsive to the scheduling event.

25. The apparatus of claim **23**, wherein the at least one processor is further configured to transmit the scheduling event as one or more of an uplink data grant, a downlink grant, an uplink channel feedback grant, or a combination thereof.

26. The apparatus of claim **25**, wherein the at least one processor is further configured:

to transmit the scheduling event as a combination of an uplink data grant, a downlink grant, and an uplink channel feedback grant; and

to determine the plurality of possible encoded uplink channels based upon the scheduling event by assuming that the served device responds to at least one scheduling event and does not respond to a combination of scheduling events that were not transmitted; and

wherein the at least one processor is further configured to detect the encoded uplink channel from the plurality of possible encoded uplink channels based at least in part on:

detecting uplink data on a first uplink channel;

detecting uplink data multiplexed with acknowledgement, channel feedback, or both on the first uplink channel; and

detecting uplink channel feedback on a second uplink channel.

27. The apparatus of claim **26**, wherein the uplink channel feedback grant on the second uplink channel comprises a periodic grant.

28. The apparatus of claim **26**, wherein uplink data comprises a persistent grant.

29. The apparatus of claim **25**, wherein the scheduling event further consists of a persistent uplink data grant.

30. The apparatus of claim **23**, wherein the at least one processor is further configured:

to transmit the scheduling event of an uplink data grant, a downlink grant, or an uplink channel feedback grant;

to determine the plurality of possible encoded uplink channels based upon the scheduling event by assuming that the served device responds to at least one scheduling event, for detecting uplink data on a first uplink channel; and

to detect uplink data multiplexed with one or more of an acknowledgement a channel feedback, or a combination thereof on the first uplink channel, and to detect uplink channel feedback on a second uplink channel.

31. The apparatus of claim **30**, wherein the uplink data grant comprises a persistent grant.

32. The apparatus of claim **30**, wherein the uplink channel feedback grant comprises a periodic grant.

33. The apparatus of claim **23**, wherein the energy detection is performed on a Physical Uplink Control Channel (PUCCH) and a Physical Uplink Shared Channel (PUSCH).

34. The apparatus of claim **33**, wherein the at least one processor is further configured to detect energy on the PUSCH from demodulation reference signals.

35. The apparatus of claim **33**, wherein the at least one processor is further configured to detect energy on the PUSCH from data and demodulation reference signals (RS).

36. The apparatus of claim **33**, wherein the at least one processor is further configured to detect energy on the PUSCH by non-coherent accumulation.

37. The apparatus of claim **33**, wherein the at least one processor is further configured to detect energy on the PUCCH in response to determining the channel quality indicator (CQI) present in a sub-frame, wherein frequency domain de-spreading of the PUCCH occurs prior to energy detection.

38. The apparatus of claim **33**, wherein the at least one processor is further configured to detect energy on the PUSCH by demodulating reference signals and channel quality indicator (CQI).

39. The apparatus of claim **33**, wherein the at least one processor is further configured to normalize detected energy on the PUCCH and the PUSCH for compensating for differing transmission power control.

40. The apparatus of claim **39**, wherein the at least one processor is further configured to scale detected energy values with respect to power spectral density offsets.

41. The apparatus of claim **39**, wherein the at least one processor is further configured to use a relative metric for the PUSCH in comparison to the PUCCH.

42. The apparatus of claim **39**, wherein the at least one processor is further configured to use an absolute metric for the PUSCH in comparison to the PUCCH.

* * * * *